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# Neoarchean crustal shear zones and implications of shear indicators in tectonic evolution of Bundelkhand Craton, central India

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**Abstract**

The gneisses and granitoids emplaced along E–W sub–vertical crustal shear zones are represented as important tectonic units in the Bundelkhand Craton. The tonalite–trondhjemite–granodiorite (TTG) gneisses (3.5–3.2 Ga; oldest unit), and streaky to mafic gneisses structurally deformed in $D_1$ deformation. The gneisses, metabasic, felsic, banded iron formation (BIF) and metasedimentaries of greenstone complex exposed in central part, have characteristics of three sets of folding ($F_1$–$F_3$) generally evolved in $D_2$ compressive phase, which are not occurring in northern part of craton. The K–rich Neoarchean granitoids (2.6–2.49 Ga) were intruded as granitic complex ($D_3$ magmatic phase) and the E–W strike–slip Raksa–Garhmau shear zone reported as important tectonic unit, evolved in a syn–to post–tectonic D3 phase. The dolerite dykes (ca. 2.0 Ga) were emplaced along NW–SE fractures in extension setting during $D_4$ magmatic event and NE–SW riedel shears occupied by giant quartz veins (reefs) evolved in Neoarchean–Paleoproterozoic during $D_5$ endogenic activity.

The relationship between macro and microstructural fabrics has been documented by mylonitic foliation, stretching lineation, S–C planes and rotated fabrics, reflect mesoscopic shear indicators, as noted in three types of mylonitic rocks. i) The rotated porphyroclasts of quartz, feldspars and asymmetric pressure shadows showing strong undulose extinction, deformation lamellae, and dynamic recrystallization are characteristic features of protomylonite where altered orthoclase and kinked plagioclase are noticed, ii) Mylonite, a distinct mylonitic foliation represented by parallel orientation of elongated quartz and feldspar with flakes of mica, iii) The ground matrix of recrystallized quartz with few protoliths of quartz and feldspar are observed, important features of ultramylonite. The asymmetric microstructures viz. σa and σb mantled porphyroclasts, other microstructures were progressively deformed by crystal plastic (non–coaxial) strain softening process under low to moderate temperature conditions. The sinistral top– to– SW sense of shear movement was dominant. The microfractures/ microfaults, kinking and pull apart structures observed in K– feldspars are indicative of overprinting of brittle deformation on ductile shearing.

**Keywords:** shear indicators, microstructures, crustal shear zone, Bundelkhand Craton, central India

## 1. Introduction

Implications of macro and microstructures observed in crustal shear zones have become more significant in understanding the tectonic growth of continental crusts in Archean cratons. The imprints of scattered features preserved in the cratons were significantly interpreted for the existence of crustal shear zones on major and minor scale. Such crustal shear zones play significant roles in exhumation of deeper crustal materials and provide passages for intrusion granitic magma into continental crust (Hutton, 1988). Shear zones are localized areas of intense deformation with large values of shear strain accumulated in these domains relative to surrounding rocks (Ramsay and Huber, 1987). Small–scale structures that developed in response to progressive simple shear in a shear zone and characterized by a protracted history of deformation are immensely useful in delineating the strain history and kinematics of a shear zone (Simpson and Schmid, 1983; Choukroune et al., 1987; Carreras et al., 2005; Passchier and Trouw, 2005).

The existence of E–W crustal shear zones in the central domains of the Bundelkhand Craton showing intensive mylonitisation, are considered potential zones to depict the tectonic evolution of Neoarchean crust. In the present paper the attempts were made to understand the tectonic significance of shear indicators of mylonites emplaced along Raksa–Garhmau shear zone. The asymmetrical shear indicators viz. rotated porphyroclasts, mylonitic foliation, S–C planes, stretching lineation and minor faults examined on mesoscopic and microscopic scales were used to decipher sense of shear movement.

## 2. Geological setting

Bundelkhand Craton belonging to northern segment of Peninsular India spreads in 29,000 km2 area in central India (Fig. 1). The eastern and western margins are bordered by Vindhyan and Bijawar basins and are separated from southern Indian block by a Central Indian Tectonic Zone(Basu, 1986). The contact between Aravalli and Bundelkhand Craton is tectonically delineated by Great Boundary fault. The northern boundaries separated by deep Himalayan basins are tectonically marked by Yamuna fault. Three important lithological complexes were identified in this cratonic block; i) TTG–gneissic complex, constituting TTG and gneisses, associated with migmatites, schists and amphibolite, ii) greenstone complex consists of supracrustal belt of basic, Banded Iron Formation (BIF) and less metamorphosed felsic volcanic - sedimentary rocks, iii) K–rich granitoids constitutes various types of granites, giant quartz veins (reefs), pegmatites and aplite dykes (Basu, 1986; Bhatt and Hussain, 2008, 2012; Bhatt and Mahmood, 2008, 2012; Bhatt and Gupta, 2009, 2014; Bhatt et al., 2011, 2017; Bhatt, 2014; Singh and Slabunov, 2013, 2015a, 2016; Slabunov et al., 2017a; Slabunov and Singh, 2018a; Singh et al., 2019a).

The oldest TTG rocks were reported in central part of the Budelkhand Craton (Sarkar et al., 1996; Kaur et al., 2014; Saha et al., 2016). Mauranipur and Mahoba gneisses dated 3.27 Ga as one set of TTG magmatism and are considered a oldest deformation phase (Mondal et al., 2002). The vast intrusive of sanukitoids, granodiorites, diorites, and high–K granites rocks were evolved during Neoarchean time (2.55–2.52 Ga; Mondal et al., 2002; Kaur et al., 2016; Verma et al., 2016; Singh et al., 2019b). A NW–SE trending dolerite dyke swarm was intruded in ca. 2000–1800 Ma (Rao et al., 2005). Patil et al. (2007) reveals that the dolerite dykes have a palaeomagnetic VGA position at about 2150 Ma. Keeping in view the complicated geological setup, the detailed field investigations were carried out and a tectonic set up was reconstructed in Raksa–Garhmau sector.

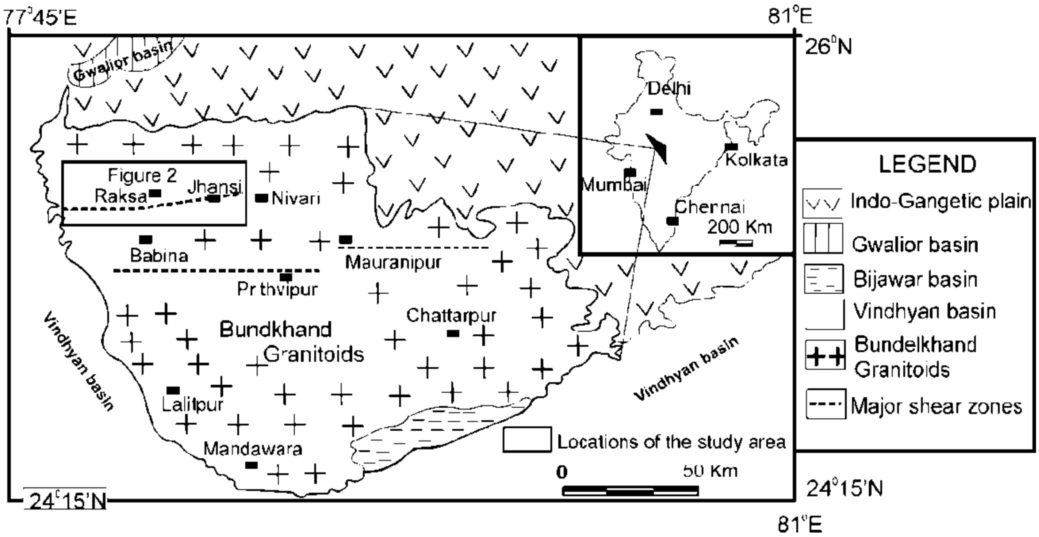


Fig. 1. Geological map of Bundelkhand Craton with location of Raksa–Garhmau sector, inset map show the location.

### 2.1 Raksa–Garhmau sector

The geology of this sector was partly discussed by Basu (1986); Senthiappan (1993); Bhatt and Gupta (2009, 2014), and Bhatt (2014). Lithologically the Raksa–Garhmau sector has broadly grouped into (i) granodioritic, and (ii) granitic complex (Fig. 2). The granodiorite gneisses are exposed in north and south of Dinara and Purwa Khiriya villages (Fig. 2) and are represented by a foliation and mineral lineation. The antiquity of TTG rocks are distinctly marked by their occurrence as smaller xenoliths (5 to 15 cm) within granodiorite gneisses (Fig. 3a).

The E–W to ESE–WNW trending foliated granitic rocks are occurred in the northern and southern extremities of Gora village and in the surroundings of the Dinara quartz reef (Fig. 2). The foliated granite was mylonitised and emplaced along E–W crustal shear zone (300–500m) near villages; Gora, Bamer, Rajapur and Shivgarh (Fig. 2). The ENE–WSW to E–W striking mylonitic foliation showing northerly dips is represented by parallel alignment of porphyroclasts of quartz, feldspar and mica flakes. The stretching lineation lying sub horizontal (5–10°) to mylonitic foliation is defined by stretched fabrics of quartz and feldspar (Fig. 3b, c). The protomylonite (Fig. 3b) to highly foliated mylonite (Fig. 3c) zones confined to the low to high shear domains were noticed in the southern terrains of Bachoni, Rajapur, Bamer, and Shivgarh villages. The fine grained ENE–WSW to NE–SW trending ultramylonites occurring near Rajapur (Fig. 3d) is bordered by pink and grey granites in north and south respectively (Fig. 2).

The enclaves of porphyritic grey granite found near Simardha, Jhansi, Bamer, and Bachoni villages constitutes large phenocrysts of feldspar (mostly microcline) and quartz (1–8 cm) with lesser amount of biotite. At some places these rocks are intruded by quartz and epidote veins and the porphyries of hornblende. These granites mainly contain fine to medium grained hornblende, bigger phenocrysts of quartz and feldspar and flakes of mica. The gneissic xenoliths (10 cm to 1 m) are also found within these granites near Simardha and south of Garhmau railway crossing.

Few fine dark green E–W lensoidal bodies (100–300 meter) of amphibolite consisting of hornblende and feldspathic minerals are exposed in the south of Raksa and north of Bamer villages. The E–W to ESE–WNW trending dark grey granite exhibiting moderate to steep dips (45–70°) are occurred in the southeast of Bamer village (Fig. 2). At places the isolated lensoidal bodies of dark grey porphyritic granite (20–60m) are occurred within the pink granite.

The massive undeformed, medium– coarse grained grey granite are widely exposed in the southern extremities of ductile–brittle shear zone near Jhansi, Shivgarh, Rajapur and Bachoni villages (Fig. 2). At few places the brittle–fractures healed by pegmatite, quartz and aplite veins are frequently seen within these granitic bodies. The higher percentage of mafic minerals and less number of potash feldspar were noticed in the coarse grained biotite granite comparatively to porphyritic coarse grained granite. The wide occurrence of medium–coarse grained pink granite is seen in the north–eastern and northern territories of Jhansi town and northern part of Bamer, Bachoni, Bamer and Garhmau villages (Fig. 2). The faulted contact between pink and grey granite is also noticed near Lahargird village. The coarse grained lensoidal enclaves of porphyritic pink granite are isolated in the southwest of Simardha village. The sheared contact with pink granite and ENE–WSW trending ductile shear zone is also recognised near Shivgarh and Lahargird villages (Fig. 2). These granitoids evolved in later phase of magmatic activity and recorded as younger granites.

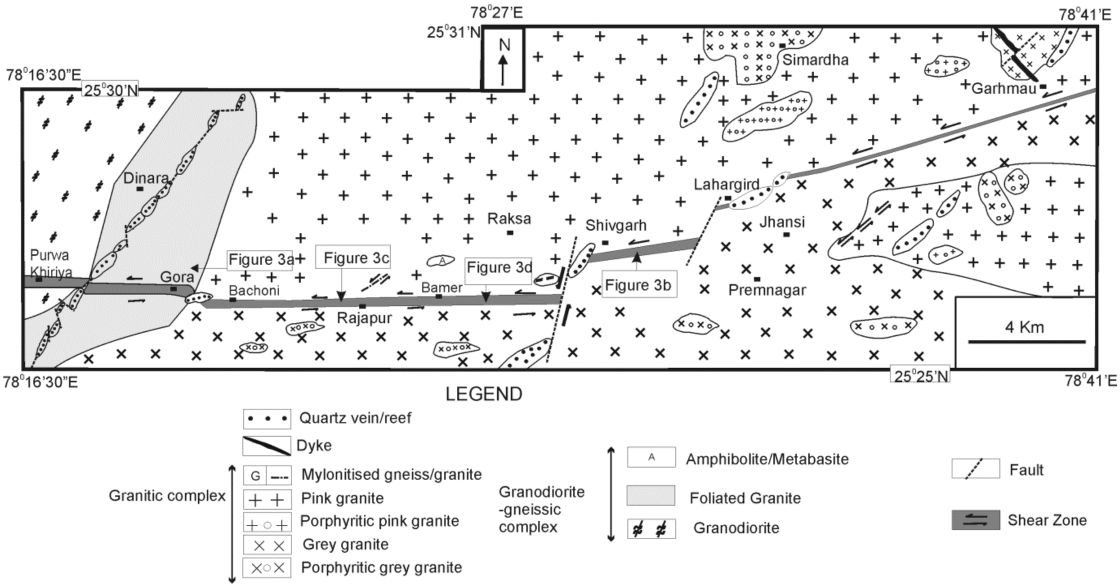


Fig. 2. Geological map of Raksa–Garhmau sector, Bundelkhand Craton, central India (after Bhatt and Gupta 2014).

Numerous NE–SW linear quartz veins (reefs) are exposed near Garhmau, Jhansi (Bundelkhand University campus), Shivagarh, and Dinara villages. The quartz reefs passing from Dinara and Purwa Khiriya and Shivagarh and Lahargird villages are offset by several NW–SE and NNE–SSW oblique faults respectively (Fig. 2). The E–W and ENE–WSW crustal shear zones are also truncated by fractures near Raksa and Lahargird villages. At places the inclined (NNE–SSW) and vertical (NE–SW) joints are observed as prominent features in these reefs. The conjugate sets of quartz veins and presence of milky to pinkish white quartz and lumps of galena and diaspore are reported as important mineral deposits.

### 3. Deformation pattern and relationship with shearing

The older TTG gneissic and greenstone sequences of Bundelkhand Craton were deformed and produced in three sets of folding ($F_1$–$F_3$) under the influence of compressive tectonic episodes ($D_1$–$D_2$; Bhatt et al., 2011; Bhatt, 2014). The different types of granitoids were elegantly exhumed along fractures and shears in the $D_3$ phase of tectonic event. The E–W crustal shear zones predominantly transecting the gneissic and granitic rocks were evolved in syn–to post–tectonic $D_3$ phase under brittle–ductile environment (Singh and Slabunov, 2015a, 2015b). The dolerite dykes were emplaced along NW–SE trending fractures in extensional tectonic setting during $D_4$ magmatic phase. The linear hillocks developed along NE–SW shears (riedel shears?) were predominantly occupied by quartz reefs in the last endogenic activity ($D_5$; Slabunov et al., 2017b; Slabunov and Singh, 2018b).

Bhatt and Hussain (2008, 2012), Bhatt and Mahmood (2008, 2012), and Bhatt et al. (2011) pointed out that the NNW to NW plunging (40–50°) $F_1$ folds showing tight and isoclinals shapes and NNE plunging (30°) open to reclined $F_2$ folds are commonly noticed in BIF, mafic and biotite gneisses, migmatites and quartz-sericite schist rocks. Their axial planes trend in N–S to NNW–SSE directions. The $F_3$ folds exhibiting open to tight geometry are plunging 45° to 50° in different directions. The elliptical folds are commonly observed in banded (mafic) gneisses. These folds occur as isoclinal plane pattern, and provide strong evidences for intensive ductile and brittle–ductile shearing in the area. Due to intense shearing effects the fold axes in tight–close folds were rotated and reoriented and at some places extensional crenulation cleavage and shear bands were formed.

## 4. Shear zones and shear indicators

The shear zones can be mapped from hand specimen to plate boundary scales and are considered vulnerable zones for reactivation over very long time span. The high shear strain domains are classified as ductile and brittle ductile shear zones and form important mechanical heterogeneities (Butler et al., 1997). The geometry of mylonitic foliation, asymmetrical fabrics and stretching lineation (Berthe et al., 1979; Matlauer et al., 1981) and implications of shear criteria (Simpson and Schmid, 1983) strongly support the criteria for the determination of sense of shear movement in most of the crustal scale shear zones. The crystal plasticity and pressure solution have been identified important mechanism to control the deformation of quartzo-feldspathic granitic rocks (Berthe et al., 1979). Passchier and Trouw (2005) discuss that the proto mylonite were initially developed under low to moderate strain conditions whereas the S–C mylonite were evolved under moderate to high shear strain conditions. Proto– mylonites, S–C mylonites and ultramylonites are recognized in Raksa–Garhmau shear zone of the Bundelkhand Craton.

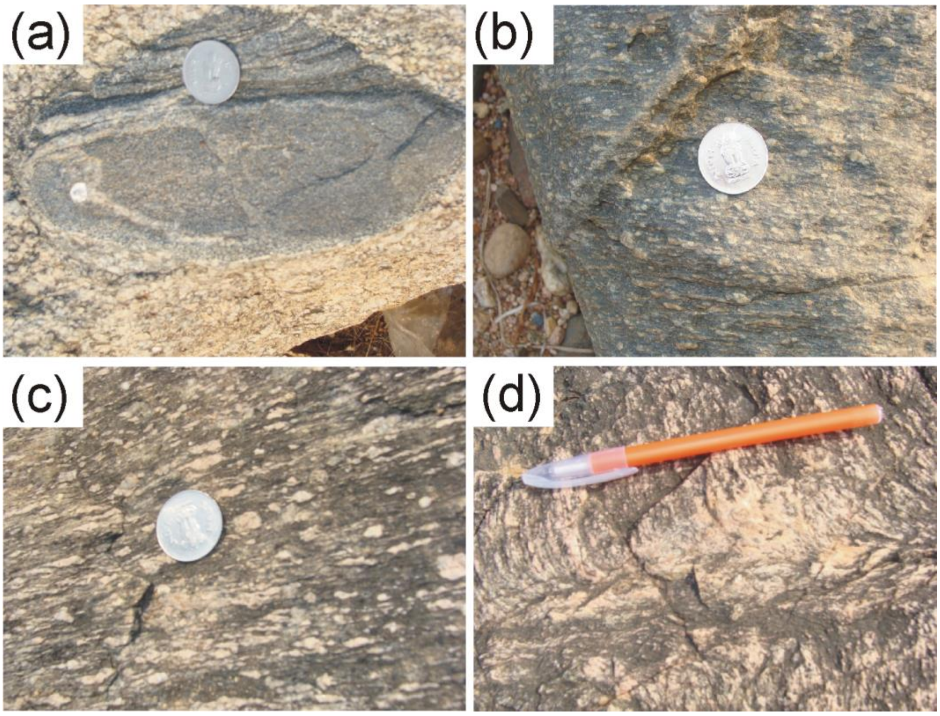


Fig. 3. (a) An enclave of TTG rock embedded within porphyritic granite gneiss; (b) Well foliated mylonitised granite gneiss showing stretching lineation and rotated porphyroclast of quartz and feldspar in protomylonite zone; (c) Intensively foliated mylonite zone showing stretched fabrics of quartz and feldspar; (d) Sheared granitic rocks showing formation of S–C mylonite zone represented by termination of S planes and evolution shear bands (C– planes). Diameter of coin is 2.4 cm and length of pen is 14 cm.

### 4.1. Raksa–Garhmau shear zone

A north dipping brittle ductile crustal shear zone (100 to 500 meter wide and about 45 to 50 km in length) transecting granodiorite gneiss and granite rocks is traced near Purwa Khiriya, Gora, Rajapur, Bamer, Raksa, Lahargird and Garhmau villages, located in the intracratonic domains of the Bundelkhand Craton (Fig. 2). Its width is consistently decreasing 100 to 50 meter near Lahargird and Garhmau villages and is possibly died out in the eastern flanks of Garhmau village (Senthiappan, 1993). The discontinuity of this shear zone is manifested by development of other sets of minor shear zones, which were at some places terminated by another shear bands (C–planes) or brittle fractures (Fig. 3d). The parallel to subparallel NE–SW trending shear zones/ riedel shears (?) were possibly evolved in syntectonic setting along which the quartz vein (reefs) were emplaced. The granites were mylonitised and emplaced along this shear zone during progressive shearing effects. This E–W to ENE–WSW trending steep crustal shear zone is sinistrally dislocated by faults near Lahargird and Raksa villages and shows dextral displacement near Dinara and Purwa Khiriya villages (Fig. 2).

The protomylonite zone consisting of large porphyroclasts of quartz and feldspar (<50%) with low percentage of matrix are widely occurred near Bamer and Bachoni villages (Fig. 3b). The mylonitic foliation striking in E–W to ENE–WSW directions is defined by preferred orientation of quartz and feldspar grains (10 mm to 3 cm) with flakes of mica exhibits steep (60°–70°) north dips (Fig. 3c). The both dextral and sinistral movement observed in the rotated pophyroclasts. However, a prominent sinistral rotation indicating top– to– SW shearing movement is exhibited by most of the porphyroclasts of quartz and feldspar. The stretching lineation defined by parallel alignment of quartz feldspar and flakes of mica lies at 10–20° to the mylonitic foliation and at few places it is displaced by minor strike slip fault and conjugate quartz veins.

The sheared genesis having S–C fabrics is marked by variation in obliquity between S and C planes. The first stage of evolution (Berthe et al., 1979) of the S–C planes is demonstrated by high degree angle (40–45°) and is remarkably noticed in the south of Rajapur village (Fig. 3d). It was observed that the major shear zone represented by existing mylonitic foliation (S–planes) was truncated by secondary C–bands (C–planes). Due to intensive effects of rotational stresses in high shear strain domains such S–C mylonites were progressively developed in major to small scale shear zones (Fig. 3d). Passchier and Trouw (2005) denoted such types of shear bands as 'c' type of shear band cleavage, which are lying at 15°–35° to main mylonitic foliation (Passchier, 1991; Blenkinsop and Treloar, 1995). A transition zone between mylonite and fine grained ultramylonite was noticed in the southeast of Rajapur village (Fig. 3d). The width these ultramylonitic bands vary from few millimetres to several centimetres.

The microstructural analysis reveals that the quartz and K–feldspar are characterized by strong undulose extinction and dynamic recrystallisation (Fig. 4a, b). The alteration effects (microclinisation) and twinning are observed in few phenocrysts of orthoclase and plagioclase respectively. The protomylonite dominantly consist large protoliths of quartz and feldspar (about 0.2 mm to 1.0 mm constitutes ~50%) with few recrystallised quartz grains and matrix (Fig. 4a, c, d). The sinistrally rotated pressure shadows wrapped by flakes of mica mainly consists of recrystallised quartz grains in the tails (Fig. 4a). A well–developed planar fabric (mylonitic foliation) and stretching lineation are present in mylonite zone. The deformation lamellae are also observed within few K–feldspar grains. The kinking and twining effects observed in few grains of plagioclase are indicative of low temperature and pressure conditions (300–400° C). The phenocrysts of quartz and feldspar were changed into elongated and ribbon shapes (aspect ratio 5:1–8:1) under intensive shearing and moderate to high shear strain conditions (Fig. 4b), selected for kinematic shearing sense.

The mantled porphyroclast of K–feldspar consisting of fine grained mantle nucleus displays $\sigma$ type of geometry (Passchier and Simpson, 1986). The $\sigma$ type of porphyroclast exhibits the top– to–left (sinistral) sense of shear movement in mylonitised granite (Fig. 4a, c). Two types of $\sigma_a$ and $\sigma_b$ mantled porphyroclasts are found in few thin sections and are distinctly characterised by two planar and curve faces. $\sigma_a$ mantled clast mainly isolated in a mylonitic matrix (Fig. 4c) whereas the $\sigma_b$ mantle clast is generally associated with S–C fabrics (Fig. 4d). The $\delta$ type mantled porphyroclast showing narrow wing and stepping are rarely noticed (Fig. 4d). In few mantle $\sigma$ porphyroclast microcracks and fracturing became prominent which led to produce bookshelf sliding structures (Fig. 4c).

The micro cracks and extensional fractures examined in few ribbons of quartz grains are indicative of overprinting of brittle deformation on ductile deformation (Fig. 4b) and were developed under low grade temperature conditions (below 300° C). Under such conditions the brittle fracturing, pressure solution and solution transfer processes became more pronounced and produced fractures, undulose extinction, deformation lamellae and kink bands in quartz and feldspar (Fig. 4a, b, c; Van Daalen et al., 1999; Stipp et al., 2002).

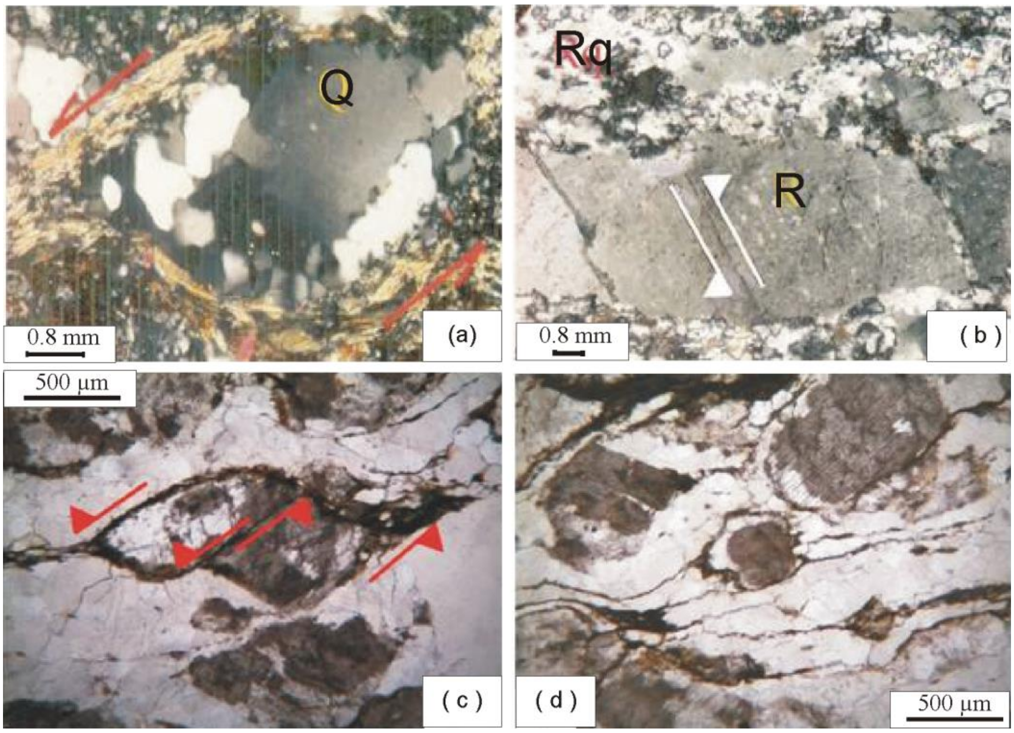


Figure 4: (a) σa mantled rotated porphyroclast of quartz (Q) forming pressure shadow and exhibiting sinistral sense of shear movement; (b) Ribbon of K–feldspar showing displaced microcracks (R) and dynamic recrystallisation quartz (Rq) in the marginal contacts; (c) σb mantled porphyroclast of K–feldspar displaced by microfaults and exhibiting bookshelf structures; (d) K–feldspar showing δ type mantled porphyroclast and deciphering sinistral sense of shear movement.

## 5. Discussion

The Bundelkhand Craton occupies the major part of northern Indian shield but its evolution in terms of crustal growth and tectonism is poorly understood (Roday et al., 1993; Bhatt, 2014, Singh and Slabunov, 2015a, 2016; Slabunov et al., 2017a; Slabunov and Singh, 2017, 2018a). The geometrical and kinematic analysis of folds and asymmetrical structures preserved in deformed and sheared rocks of Babina and Mauranipur area, infer that the Archean gneissic complex was characterised by three different sets of folding ($F_1$–$F_3$). The $F_2$ and $F_3$ (open to reclined) folds were displaced orthogonally by sheared planes in the later episode of shearing (Bhatt and Hussain; 2008, 2012; Bhatt and Mahmood; 2008, 2012; Bhatt et al., 2011). The mesoscopic and microfabric analysis reveal that the crustal shear zones emplaced along central domains of Bundelkhand Craton were syn–tectonically deformed during progressive shearing under low temperature–pressure conditions in a brittle–ductile environment.

Under low to moderate shear/ strain conditions, the protomylonite containing bigger porphyroclasts of quartz and feldspar were evolved and shows the higher percentage of (50–90%) of these relic fragments (Passchier and Trouw, 2005). The asymmetrical geometry of porphyroclasts (quartz and feldspar) and pressure shadows and angular relationship between S–C fabrics imply that the mylonites were produced under the influence of non–coaxial (simple shear) deformation in a ductile regime under low to medium temperature conditions. Due to intensive deformation the elongated and ribbon shaped quartz and feldspar grains were developed under high strain conditions and noticed that the degree and intensity of deformation was consistently increased from margin to central part of the shear zone. The small scale minor faults were also developed in the later stage of deformation in cataclastic regime and under brittle conditions (Fig. 3d). The sinistral movement of microfaults displayed by few phenocrysts of quartz and K–feldspar were produced in brittle deformation under cataclastic regime (Fig. 4b).

The development of pressure shadow and elongated to ribbon fabrics was possibly controlled by pressure solution and dynamic recrystallization under moderate to high shear strain conditions. The undulose extinction, deformation lamellae, and dynamic recrystallisation characteristics of strain softening processes in plastic deformation of quartz grains in ductile and low to medium temperature conditions (Pryer, 1993; Ji, 1998a, 1998b; Hippertt and Hongen, 1998; Passchier and Trouw, 2005), evident in the Bundelkhand Craton. The crystal plastic deformation became dominant under moderate to high temperatures and led to initiate the dynamic recrystallisation and stretching of quartz and feldspar (Pryer, 1993; Stipp et al., 2002; Passchier and Trouw, 2005).

The mylonitised rocks formed under the influence of low to medium shear strain and temperature conditions in a non–coaxial flow at marginal contacts. The rotated porphyroclasts, S–C fabrics and other asymmetrical structures dominantly exhibit sinistral top- to- SW shear movement. The presence of microcracks and minor faults are indicative of overprinting of brittle shearing on ductile shearing. The mineral assemblages and geometrical orientations in newly formed mylonites were changed due to excessive effects of simple shear (non–coaxial deformation) and pressure solution. The geometry of C–surface and extensional crenulation cleavage provide strong evidences for predominance of extensional tectonics in the development of ductile shear zones at late stages. The ductile shearing took place in the initial phase of deformation and subsequently followed by brittle shearing in late stages of deformation.

The presence of $\sigma_a$ mantled porphyroclasts in moderate to high strain shear zones infer that these fabrics were evolved under the influence of crystal plastic deformation (Passchier and Trouw, 2005). The twinning and kinking displayed by few grains of plagioclase imply that the mylonites were deformed in a specific crystal plastic deformation under lower temperature and pressure solution conditions (Passchier and Trouw, 2005). Quartz forming the main constituents of matrix in mylonite has been excessively affected by grain size reduction in ductile regime. The most of phenocrysts of quartz and feldspar were subjected to strain hardening due to instant decrease in strain rate and enhancement of differential stresses. Eventually the extensional cracks and brittle fractures were formed in cataclastic regime. The microfracturing, bookshelf structures, kinking examined in K–feldspar and plagioclase are indicative low temperature and brittle deformation conditions. The back rotation of foliation between closely spaced shear planed are occurred due to progressive effects of shearing and eventually produced crenulation crinkles.

The ubiquitous presence of mylonitic foliation, stretching lineation, asymmetrical rotated porphyroclasts, and S–C fabrics imply that the brittle–ductile to ductile crustal shear zones in the Bundelkhand Craton were evolved under the influence of moderate to high shear strain. Due to lack of evidences, it would be difficult to differentiate between younger and older movement of these shear zones. The imprints of folding are not found in the rocks of the K–rich granitoids while it formed in subduction environment, later it was followed by extensional tectonics during the synmagmatic granitic diapirism (Neoarchean).

The oldest gneisses of this craton associated to metabasic enclaves were subjected to earlier magmatism and metamorphic melting at ca. 3.3–3.2 Ga. This event may be corresponding with the $D_1$ phase of deformation in the present work. The major compressive tectonic phase ($D_2$) responsible to generate three sets of folding ($F_1$–$F_3$) in basics, TTG–gneisses, BIF with metasedimentary rocks took place between ca. 3.2 to 2.7 Ga. Saha et al. (2011) pointed out that the Babina greenstone rocks was record high presure at 18–20 kbar and ca. 630° C to lower metamorphic P–T conditions of 11±3 kbar ca. 630° C at ca. 2.78 Ga age. It may reveals that the Neoarchean high pressure metamorphism in the craton be associated with $D_2$ phase of tectonic compression. The 2.57–2.54 Ga K-rich granitoid resemble with extensive magmatic phase ($D_3$) of Bundelkhand Craton (Singh et al., 2019b; Slabunov and Singh 2018a).

The field setting and other signatures infer that the quartz reefs were exhumed from the intermediate to shallow depth crustal levels along NE–SW trending shear zones. Some mylonitised granitic rocks were also sinisterly displaced by NE–SW oblique faults and may be formed due to emplacement of huge quartz reefs (endogenetic movement) in ductile to brittle environment.

## 6. Conclusions

Based on above observations, the following conclusions can be drawn:

i) The TTG gneisses, mafic and streaky gneisses along with amphibolite and schist were deformed and folded in two regional compressive tectonic phase ($D_1$–$D_2$). The main phase of granitic intrusion probably took place in $D_3$ magmatic phase (2.57 to 2.5 Ga) along major fractures and shear planes.

ii) The subvertical E–W trending Raksa– Garhmau shear zone, is strike slip crustal shears, reveal sinistral top–to– SW (left lateral) shear movement and were evolved at intermediate to shallow depth within intracratonic domains of Bundelkhand Craton in late $D_3$ phase.

iii) The shear indicators infer that the mylonites were evolved under crystal plastic and strain softening processes in brittle – ductile (non – coaxial) environment under low to moderate temperature conditions.

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